Empirical Investigation into the Limitations of the Normative Paired Sales Adjustment Method

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Abstract. **This study investigates the normative paired sales adjustment method employed by appraisers in the sales comparison approach. It finds that the method fails to account for the diminishing marginal price effects of property attributes. The study develops an empirical model to test the marginal price effects of view and lot-size amenities. The finding is that the empirical data confirm land economic theory and identify a need to study and develop improved methods for estimating adjustments to comparable sales.**

Introduction

In a summary of critiques of traditional appraisal theory, Pearson (1988) reiterates that the sales comparison approach is the most appropriate technique for estimating probable sale price and recognizes the important role that statistical analysis should play. It has been noted, however, that the appraisal industry has been slow to adopt new ideas and concepts.[1] One such example is the industry's continued reliance on matched pairs to estimate the amount of adjustment for physical differences between properties. Though an accepted, normatively expected practice, the method is limited in all but the simple case of evaluating the presence or absence of a property attribute that varies in neither magnitude nor quality.

Smith's (1995) essay addressing the concept of most probable price assumes that the data have been appropriately adjusted to reflect subject property attributes. He notes, however, that "...this is probably an unrealistic assumption, because appraisers tend to be victimized by linear trend lines." Brotman (1990) confronts the linearity issue but does not derive or test an underlying theory in support of nonlinear models. Further, she does not report variations in mean squared error among the several models tested.

This article pursues the question of whether linear paired sales analysis facilitates appropriate adjustments for metrically varying quantities or qualities of a property attribute. In addition to this primary focus, the data provide insight into how the residential market responds to variability in the quality of a view amenity and provides

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an objective means to quantify view metrically and thus derive better lot price estimates.[2]

Sales comparison is used to estimate market value by comparing the property subject to appraisal to similar, recently sold properties.[3] Adjustments for differences between recently sold comparable properties and the subject property are based on market extractions, with paired sales analysis being the normative model for extracting adjustment amounts. Boyce and Kinnard (1984) define paired sales analysis as a ‘‘method of estimating the amount of adjustment for the presence or absence of any factor, *or for varying quantities of any factor*, by pairing the sales prices of otherwise identical properties with and without the factor in question’’ (emphasis added).

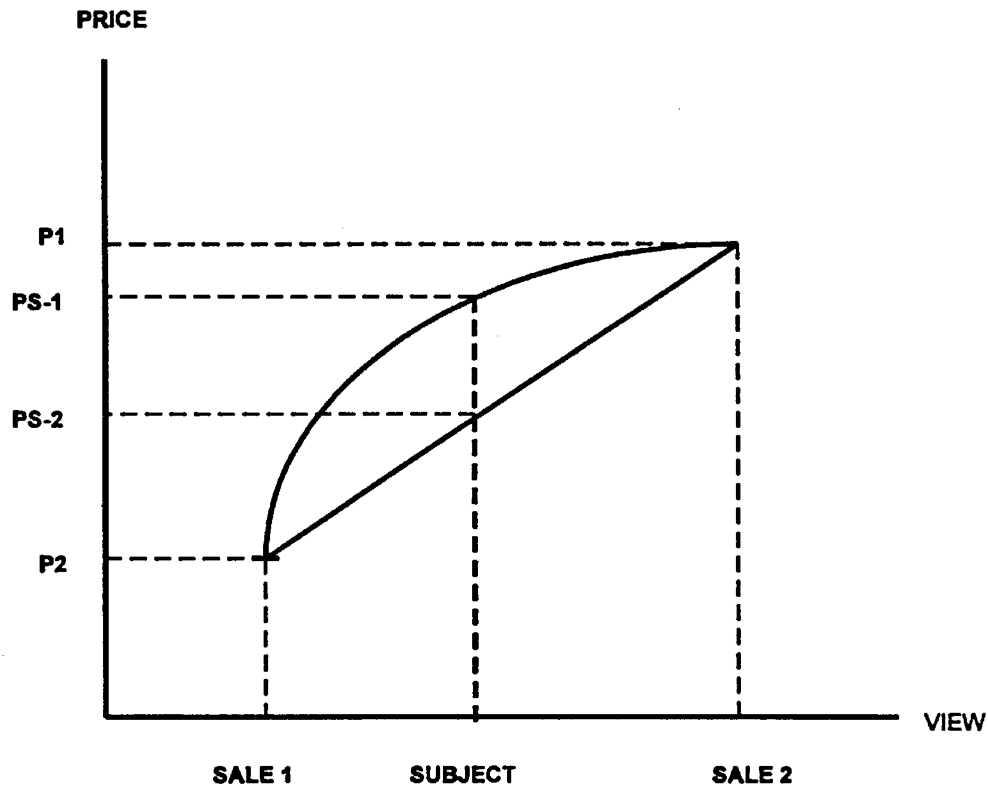
Given that two points can only define a straight line, the pairing of sales to extract market adjustments invokes an implied linear relationship between price and the variable under consideration. If the price effect is not linear, however, paired sales derived adjustments may over- or understate the required adjustment amount. The degree of error depends on both the extent to which the price effect departs from linearity and the relative difference between the paired sales with regard to the variable of interest.

Consider the two comparable sales identified as Sale 1 and Sale 2 in Exhibit 1. Each sale includes information concerning a measurable amount of view amenity (shown on the horizontal axis) and a corresponding, observable sale price P1 and P2 (shown on the vertical axis). If the properties are similar in all other respects and representative of market prices, then the difference in price represents the difference in the value of view.

Now consider a subject property undergoing appraisal (labeled ‘‘subject’’ on the horizontal axis). Its view is observable, but its price is unknown. If the subject property is similar to Sales 1 and 2 in all respects except view, then the market price for the subject property should fall between P1 and P2. If the view price effect is linear as implied by the use of matched pairs, then PS-2 represents an appropriate estimate of market value for the subject property. If the price effect is nonlinear and diminishing as indicated by theory that is reiterated later, then (assuming that the curved line in Exhibit 1 is an accurate representation of the price effect) PS-1 represents the appropriate market value estimate.[4]

The sections that follow review the theory underlying the expectation that property attributes exhibit diminishing rather than constant (linear) marginal price effects. Empirical residential lot data, which exhibit variation in lot size and view, are presented and subjected to a structural modeling investigation. The results strongly support a conclusion of diminishing marginal price effects for lot size and view, calling into question application of the paired sales procedure to metrically varying property attributes.

Exhibit 1
Graphic Illustration of Linear and Nonlinear Price Effects



Consumer Theory and Site Choice

Alonso's (1964) residential site choice model employs consumer theory to explain behavior concerning choice of household location. He develops a utility-optimization model whereby households maximize their satisfaction subject to an income constraint.

Diamond and Tolley (1982) build on the Alonso model in their analysis of markets in site-specific amenities. Their study starts with a one-period perspective for a household with one residence location. The household allocates its income to consumption of land, site-specific amenities and other goods in a manner that maximizes household utility (*U*), subject to an income constraint, as follows:

$$Max\ U(Q, a, Z)\ s.t.\ Y = Z + P_L(a)Q, \tag{1}$$

where *Y* is household income, *Z* is a composite good, *a* is a vector of all amenities available at the site, P_L is the marginal price for land at a point in amenity space and

Q is the quantity of land. The first-order conditions for household equilibrium result in the following relationship:

$$U_a/U_z=(\partial P_L/\partial a_i)Q. \tag{2}$$

Equation (2) provides insight into the amenity value question because, when divided by Q, it becomes:

$$v_a/Q=\partial P_L/\partial a_i, \tag{3}$$

where v_a is defined as U_a/U_z or the marginal value per unit of land of all amenities contained at a site in terms of money. Because the supply of land with a given amenity bundle is fixed over a one-period perspective, P_L is demand-determined. Therefore, households set market price increments by marginal bids for additional amenities. At the same time, the market can be expected to provide price signals regarding the value of amenities embodied in a given site. Diamond and Tolley go on to suggest that implicit amenity price coefficients can be empirically examined by regressing land price on amenity levels inherent in specific sites. In a given market period, vacant lots are priced in the real estate market according to the value placed on incremental differences in site-specific amenities. The pricing is functionally represented as:

$$P_{LOT}=P_{LOT}(a_1,\ a_2,\ ...\ a_n), \tag{4}$$

where P_{LOT} is the price of a given residential lot and a_n is a vector of amenities inherent in the lot, including lot size as a dimension of the amenity vector.

Borland (1990) incorporates property tax into the model by recognizing the sale price of housing sites (SP) as:

$$SP=MVPA+[PVPS+t_N AV/r], \tag{5}$$

where $MVPA$ is the market value of property attributes, $PVPS$ is the present value of periodic public services, t_N is the nominal property tax rate, AV is the assessed value and r is the rate of discount where property tax liabilities are assumed to remain constant in real terms. Sales prices are reflections of property attributes ($MVPA$) plus the net tax.[5] However, it is reasonable to exclude $PVPS+t_N AV/r$ from model specification when submarket segments are delineated to encompass properties with equal net taxes.

Rosen (1974) points out that market-clearing prices (P_{LOT}) are determined by distributions of consumer tastes (u), income (Y) and producer costs. On the demand or consumption side, he defines a value function $\theta(a_1, a_2, ... a_n; u, Y)$ as representative of the expenditure a household is willing to make for different values of $(a_1, a_2, ... a_n)$. Rosen then shows mathematically that the value function is increasing in a_i (assuming that the a_1 are "goods" rather than disamenities) at a decreasing rate.

Based on the foregoing, the linear price effect assumption implicit in the normative model for extracting adjustment amounts (paired sales) does not conform to theory. In other words, when paired sales are used to estimate the marginal rate of substitution between property amenities (a_i) and money, the technique implicitly assumes that the amenity value function is increasing in a_i at a constant rate.

Regression Model and Research Hypothesis

Based on Palmquist (1984), the estimation of a regression of sale prices on property attributes during a market period reveals little about underlying demand unless all consumers are identical. This is equivalent to controlling for u and Y in the value function $\theta(a_1, a_2, \ldots a_n; u, Y)$ in order to model demand with a sale price regression. In this investigation, the data were selected to block for consumer taste and income to the extent possible in an uncontrolled setting.[6] Taste was controlled by narrowly defining the location and attributes of the lot sales employed in the analysis. Because the narrowly defined location includes only relatively expensive homes and residential lots, buyers are all expected to come from the market's upper income segment.[7]

To test the structure of marginal amenity price effects, the Kang and Reichert (1987) composite double-log/semi-log model was chosen to represent the hypotheses. The model is essentially the same as that employed by Colwell (1990) in a study of power lines and that used by Pollard (1982) to investigate view amenities and building height in the Chicago apartment market. The relational model is

$$SP=(\exp^{\alpha_1 D_1+\alpha_2 D_2+\ldots+\alpha_m D_m})\, X_1^{\beta_1}\, X_2^{\beta_2} \ldots X_p^{\beta_p}, \tag{6}$$

where SP represents lot price, D_i is a vector of property characteristics specified as dummy variables and X_i is a vector of metrically measured property attributes. The present study incorporates three dummy variables, which are defined fully in the next section [developability (*DEV*), proximity one (*PROX1*) and proximity two (*PROX2*)], and two metric variables [lot size (*SIZE*) and view (*VIEW*)]. The estimation model in Equation (7) is the logarithm of Equation (6) with the appropriate variable substitutions for D_i and X_i as follows:

$$ln(SP)=\beta_0 + \beta_1(DEV)+\beta_2(PROX1)+\beta_3(PROX2)+\beta_4[ln(SIZE)]+\beta_5[ln(VIEW)]. \tag{7}$$

If marginal price effects diminish, then β_4 and $\beta_5<1$. This research hypothesis, assuming that *SIZE* and *VIEW* are "goods" and have significant price effects, is summarized as $0<\beta_4, \beta_5<1$.

The Data

To develop a useful lot valuation model it is essential to gather sufficient lot sale data and thus regress observed lot price on amenity characteristics specific to each lot. Hair, Anderson, Tatham and Black (1992, p. 46) note that "R^2 is influenced by the number of predictor variables relative to the sample size." They prefer a range of ten to fifteen observations per independent variable, with four as the absolute minimum. The present study includes fifty-six observations and five initial predictor variables, a ratio of roughly 11 to 1. After two variables are deleted from the model, the ratio reaches roughly 19 to 1. Therefore, the data set is reasonably sized.

The data set was limited to vacant lot sales within a prespecified location to control for variation in household income and other exogenous price influences. The location is a one-mile-wide by six-mile-long neighborhood located north of Tucson, Arizona, adjacent to the Coronado National Forest. Lots in the location are situated in the foothills of the Catalina Mountains; thus, many provide excellent views of the city to the south. In fact, views are particularly spectacular at night and command substantial price premiums. The submarket is further typified by relatively large and expensive custom-built homes on lots ranging in size from approximately one-half acre to more than three acres. Other common features of the location include reliance on county government and an approximately five mile commute to the city on surface streets. In addition, all properties are located in the same school district. Additional exogenous influences were accounted for by restricting the data to lots within guard-gated, master-planned communities. All lots have equivalent elevation above sea level and uninterrupted views of the mountains to the north.

Quality of view of the city (*VIEW*) varies with the degree to which a home site is blocked by natural topography, other homes or homes expected to be built in the future. Lot size (*SIZE*) in the data set varies from 0.63 acre to 3.34 acres. The area's topography also affects site developability (*DEV*). While most of the lots in the data set exhibit relatively minor developability problems, seven of the lots are constrained by severe developability problems that require unusually high expenditures for fill and foundation work.

Real estate brokers active in the area suggest that two additional factors could affect lot prices. The factors are ''being contiguous to subdivisions without guarded entry gates (*PROX1*)'' and ''abutting the national forest (*PROX2*).'' As shown later, however, these two factors are determined insignificant and ultimately deleted from the final model.

Lot sale data were acquired from public records for Pima County. Inspection of each lot sale involved measuring city view, identifying adjacent land use and noting any developability constraints. Lot size was based on site surveys recorded with subdivision maps or on file at sales offices, thereby allowing good control of lot size measurement error. City view was metrically scaled in terms of the width of each lot's angle of city-view panorama, adjusted for blockage and potential future blockage from neighboring homes. The goal was to measure what the lot buyer saw when the lot was considered for purchase.[8]

The final step in the data collection process was to contact someone knowledgeable about the circumstances of each sale to facilitate elimination of sales involving atypical motivations or unusual circumstances. This step reduced measurement error

Exhibit 2
Descriptive Statistics

	Lowest Value	Highest Value	Range	Mean	Std. Dev.
PRICE ($)	90.00	345.00	255.00	173.31	62.30
SIZE	0.63	3.34	2.71	1.26	0.53
VIEW	10.00	160.00	150.00	52.23	45.77
DEV	0.00	1.00	1.00	0.13	0.33
PROX1	0.00	1.00	1.00	0.18	0.39
PROX2	0.00	1.00	1.00	0.21	0.41

in the dependent variable by limiting observations only to those sales that appeared to be market transactions.

Fifty-six residential lot sales were retained from four competitive subdivisions. The sales occurred over a roughly four-year period from 1988 through 1991. The time frame covers a stagnant period in Tucson real estate development following a spurt of activity in the early 1980s. No new directly competitive products entered the market during this time period; therefore, amenity prices were primarily demand-determined. In addition, prices were relatively stable over this period. Consequently, the sales are representative of a one-period perspective and require no adjustment for price change over time.[9]

For entry into the model, *SIZE* was measured in acres and *VIEW* in degrees of rotation around the center of the home site, with 180 degrees as the highest possible score (all lots had 180-degree mountain views to the north). *DEV*, *PROX1* and *PROX2* are nominal inputs signified by dummy variables. The dependent variable *SP* was measured in dollars per lot. Exhibit 2 presents descriptive statistics for the variables and Exhibit 3 a correlation analysis.

Empirical Results

Exhibit 4 presents estimation results from Equation (7). The full model ordinary least squares (OLS) regression included all five independent variables. Although sales

Exhibit 3
Correlation Analysis

	PRICE	*SIZE*	*DEV*	*VIEW*	*PROX1*	*PROX2*
PRICE	1.000					
SIZE	0.537	1.000				
VIEW	−0.027	0.125	1.000			
DEV	0.878	0.446	0.231	1.000		
PROX1	−0.114	0.244	−0.035	−0.234	1.000	
PROX2	−0.230	−0.137	−0.197	−0.227	−0.243	1.000

Exhibit 4
OLS Regression Results

Independent Variable	Reduced Model Coeff. (t-Stat)	Full Model Coeff (t-Stat)
Intercept*	10.97	11.04
	(103.1)	(89.7)
Ln(*SIZE*)*	0.20	0.22
	(2.9)	(2.9)
DEV*	−0.29	−0.30
	(−4.0)	(−4.2)
PROX1		−0.04
		(−0.6)
PROX2		−0.08
		(−1.3)
Ln(*VIEW*)*	0.29	0.28
	(9.5)	(8.4)
R^2	.7236	.7324
Adjusted R^2	.7076	.7057
Root MSE	.1706	.1712
F-Statistic	45.377	27.373

*Significant at α=.01.

agents at some of the properties indicate that adjacency to the National Forest (*PROX2*) may be a desirable amenity, the adjacency variable is not significant at the 5% level and does not carry the expected sign in the regression equation. Proximity to less costly subdivisions (*PROX1*) was expected to be a disamenity and carries the expected sign, but it is not significant at the 5% level. Therefore, the adjacency and proximity factors appear to have little influence on the lot price outcome.

Both adjacency and proximity variables were dropped from the analysis. The result is shown as the reduced-form model in Exhibit 4. Justification for dropping *PROX1* and *PROX2* from the regression analysis to create the reduced-form equation is based on the min-MSE criterion discussion in Neter, Wasserman and Kutner (1990), and is equivalent to the max-adjusted R^2 criterion. The adjusted R^2 for the full model is .7057. It increases slightly to .7076 in the reduced-form model. The reduced-form regression result follows:

$$ln(SP)=10.97-.29(DEV)+.20[ln(SIZE)]+.29[ln(VIEW)], \tag{8}$$

and the coefficient of determination (R^2) is .7236.

The studentized residuals from the reduced-form regression result were examined for normality by using the PROC UNIVARIATE routine in SAS. The p-value was .2785, indicating failure to reject the SAS routine's hypothesized normal distribution of the error term. However, an examination of a plot of studentized residuals versus price revealed some evidence of heteroskedasticity. White's (1980) test rejects a homoskedasticity hypothesis at the 5% significance level (χ^2=17.4619, *p*-value=.026).

Such a finding is not unusual in hedonic models, but when the regression model is heteroskedastic, the estimators are inefficient and the variance estimates biased. Inference procedures relying on the assumption of homoskedastic variance are unreliable in these instances. Neter, Wasserman and Kutner (1990) offer a weighed least squares (WLS) procedure for dealing with heteroskedasticity that involves estimations of weights derived from the data. Their procedure is similar to that used by Fehribach, Rutherford and Eakin (1993) and by Ambrose (1990). The best fit to the absolute value of the OLS residual [*ABS*(*RESIDUAL*)] was the following quadratic equation:

$$ABS(RESIDUAL)=f[ln(VIEW),\ ln(VIEW)^2,\ ln(SIZE),\ ln(SIZE)^2]. \tag{9}$$

The correlation coefficient for Equation (9) was .3006 and the *F*-Statistic 5.479, yielding a *p*-value of .001. Exhibit 5 presents the WLS result. White's (1980) test of the WLS result has a *p*-value of .5202, strongly supporting the SAS routine's assumption of a homoskedastic WLS error term. The WLS model's inferential statistics indicate that all the independent variables are highly significant (*p*-values of .0001), with an *F*-Statistic of 189.11 supporting the overall significance of the model.

The final WLS model is specified as follows:

$$ln(SP)=11.02-.33(DEV)+.23[ln(SIZE)]+.27[ln(VIEW)]. \tag{10}$$

Exhibit 5
Reduced-Form WLS Results

Independent Variable	Coeff. (*t*-Stat)
Intercept*	11.02
	(152.1)
Ln(*SIZE*)*	0.23
	(6.5)
DEV*	−0.33
	(−5.7)
Ln(*VIEW*)*	0.27
	(12.95)
R^2	.9160
Adjusted R^2	.9112
Root MSE	1.2017
F-Statistic	189.111

*Significant at α=.0001.

Both lot size and view carry coefficients that are less than 1, indicating decreasing marginal utility. Confidence regions around the coefficients indicate that $H:_O$ $\beta_{LN(SIZE)} \geq 1$ and $H:_O$ $\beta_{LN(view)} \geq 1$ are rejected at a 0.1% significance level. The 99.9% confidence interval for $\beta_{LN(SIZE)}$ is $.234 \pm .126$ or .108 to .360. The 99.9% confidence interval for $\beta_{LN(view)}$ is $.272 \pm .073$ or .199 to .346.[10] Therefore, the empirical analysis strongly supports the research hypothesis of $0 < \beta_4$, $\beta_5 < 1$.

Based on this result, it follows that a nonlinear model should outperform a linear model as a sale price estimation tool. Cross-validation is employed as a means to test this conclusion. The data set is divided into two components to ascertain the effectiveness of linear and nonlinear valuation models.[11] A nine-lot holdout sample is randomly selected, with the remaining forty-seven observations used to derive linear and quadratic regression models. The linear model, $SP = f(DEV, SIZE, VIEW)$, results in a R^2 of .8567 and an adjusted R^2 of .8467. The nonlinear model, $SP = f(DEV, SIZE, SIZE^2, VIEW, VIEW^2)$, results in a R^2 of .8713 and an adjusted R^2 of .8556. The linear model's lower adjusted R^2 indicates that the quadratic (nonlinear) terms account for systematic price variation. Therefore, the nonlinear model should be a better valuation tool.

Price estimates are derived for the nine-lot holdout sample by using the linear and quadratic regression models. Exhibit 6 presents the results. The correlation between actual sale price and the linear model's price estimates is .9072, and the correlation between actual price and the nonlinear model's price estimates is .9565. Use of a holdout sample, therefore, reveals that the nonlinear model is a more accurate price estimation tool, at least for this data set.

Conclusion

The study result supports theories grounded in land economics and shows that appraisers should question the universal applicability of the normative, paired sales

Exhibit 6
Linear and Nonlinear Price Estimate Comparisons

Holdout Observation Price ($)	Linear Price Estimate ($)	Nonlinear Price Estimate ($)
125,000	128,862	128,193
150,000	150,525	148,903
140,000	147,417	148,812
156,750	138,384	141,663
146,250	139,255	138,163
185,000	221,788	211,058
156,000	156,281	148,601
142,500	146,502	151,165
290,000	248,420	267,426
Corr. Coeff.	.907	.957

adjustment procedure and its implied linear relationships. The internal validity of the finding is facilitated by the design of the investigation, which reduces model complexity by eliminating housing characteristic variables and exogenous variation. In addition, the study reveals the structural relationship between price and the variables of interest. Caution is urged, however, when generalizing from these findings to other markets and property attributes.

Confirmation of the diminishing marginal price effect structure of amenity versus sale-price relationships and the investigation's method of measuring view should be of interest to tax assessors, appraisers and land developers faced with the task of pricing subdivision lots, especially in situations where large lot-to-lot disparities in amenity price premiums can and often do occur. Likewise, review appraisers and loan underwriters can do a better job of assessing loan collateral when they understand the limitations of the paired sales methodology.

These findings indicate that the normative appraisal model may need to be studied further to derive improved methods for estimating adjustments to comparable sales in the widely used sales comparison approach. Additional inquiry is needed to uncover the structure of price effects for other data sets, property types and locations.

Notes

[1]Wendt (1969) attributes the sluggish rate at which the appraisal profession embraces innovation to bureaucratic barriers to dissemination of new ideas and to professional standards review committees that stifle innovation and discourage criticism of accepted appraisal theory. At present, given the existence of a national Appraisal Standards Board, barriers to innovation in the professional ranks appear to be even more formidable.

[2]Several authors, including Rodriguez and Sirmans (1994), Do and Sirmans (1994) and Plattner and Campbell (1978) have dealt with view as a dummy-coded variable. An implicit assumption underlying the dummy-variable method of measuring the value of a view is that all views are equal in value; that is, either a view exists or does not exist. Pollard (1982) recognized that view quality can and does vary. His article appears to stand alone in not treating view as a binary variable.

[3]The Appraisal Institute, *The Appraisal of Real Estate*, 10th ed., Chicago: Appraisal Institute, 1992.

[4]Manipulation of Exhibit 1 by moving the subject property closer to Sale 1 or Sale 2 or by reducing the distance between Sale 1 and Sale 2 reveals that estimation error is greater when the comparable sales are more dissimilar and/or the subject property is near the center of the distance. A limitation of the paired sales adjustment method is therefore a need for sale data that are not markedly different from the subject property. Overcoming this limitation may at times be difficult when faced with the vagaries of real world data.

[5]The net tax is the difference between tax incidence and tax benefit. For example, a household's net tax would be negative if the household's tax incidence exceeded its tax benefit.

[6]Blocking for variation in taste and income is equivalent to delineating a neighborhood in an appraisal in order to focus the comparable sale search within a location that is likely to be considered by buyers as an acceptable substitute for the subject property location. The data were initially collected as part of an appraisal assignment based on a determination of subdivisions that offered substitute properties competitive with the lots being appraised.

[7]According to Straszheim (1975, p. 5), there is a ''high correlation between the quality of a neighborhood's housing stock, housing prices and income of neighborhood occupants.''
[8]While some subjectivity may be involved in this measurement technique, especially when expected future homes have not been built, angle of panorama is in fact quantifiable. Because this method allows the appraiser to allow for varying qualities of view, it is superior to simple ''yes'' and ''no'' measurements of view.
[9]A reduction in sales activity provides evidence that the market had become stagnant. The data set contains twenty-seven sales from 1988, seven from 1989, ten from 1990 and twelve from 1991. In addition, indicator variables for 1989, 1990 and 1991 sales (*YR89*, *YR90* and *YR91*) were added as regressors to the reduced-form OLS model to test the hypothesis that *YR89*, *YR90*, *YR91*=0. The regression fails to reject this hypothesis for all three years. Respective *p*-values were .5135, .1257 and .3949. While the validity of this assumption is borne out, other data sets may require inclusion of a time factor.
[10]$t_{(.001,52)}=3.4877$
Std. Dev. $\beta_{LN(SIZE)}=.036274$
Standard Deviation $\beta_{LN(VIEW)}=.021025$
99.9% Conf. Interval for $\beta_{LN(SIZE)}=.23423\pm.036274(3.4877)$
99.9% Conf. Interval for $\beta_{LN(VIEW)}=.27223\pm.021025(3.4877)$
[11]See Freund and Littell (1991, pp. 52–54), for a discussion of this procedure.

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